Disclaimer: This study has been developed under the European Investment Bank (EIB) STARBEI funding program.

Source: http://www.pkeresearch.com/research/green-telecom-networks

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ENERGY CONSUMPTION FORECAST IN 4G NETWORKS: THE CASE OF SPAIN

Rafael Coomonte
Sergio Ramos
Claudio Feijóo
José-Luis Gómez-Barroso

European Investment Bank

CeDint Politécnica

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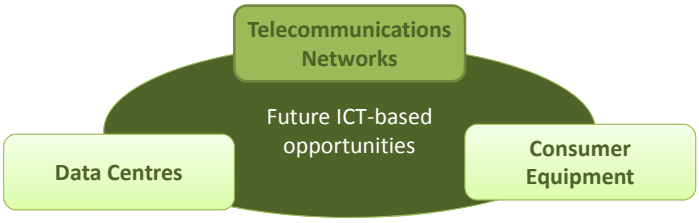
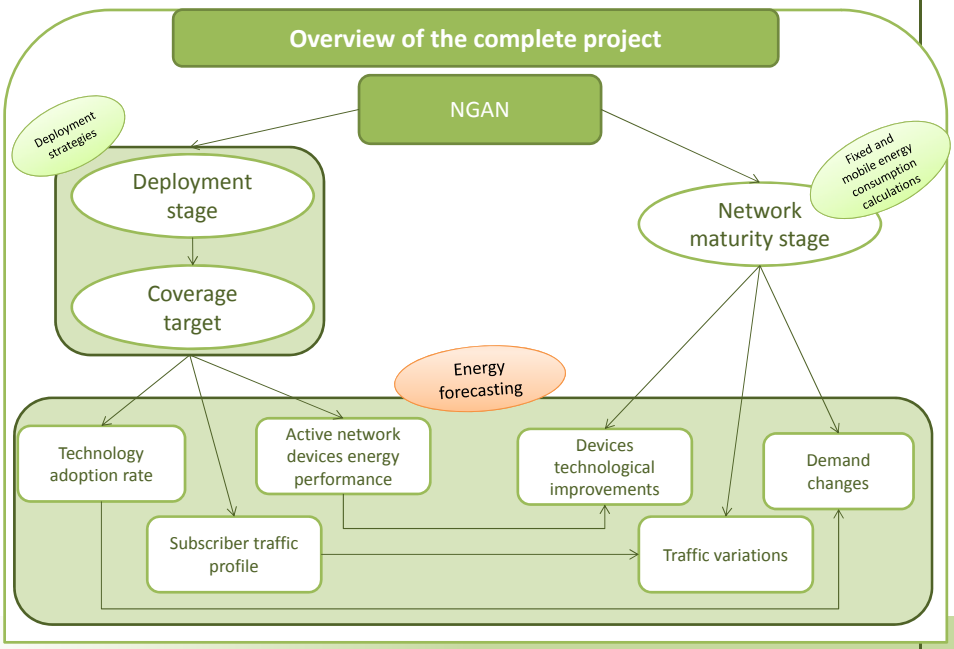
Introduction

- **Reducing energy consumption** is one of the main goals of sustainability planning in most countries. For instance in Europe, the EC established the objectives in the Communication "20 20 by 2020 Europe's climate change opportunity".



- Next Generation Networks (NGN) → **One of the most relevant upcoming ICT development**
- The role of energy consumption seems mostly **absent** from the main analysis and the debate on NGN deployment.

Overview of the complete project



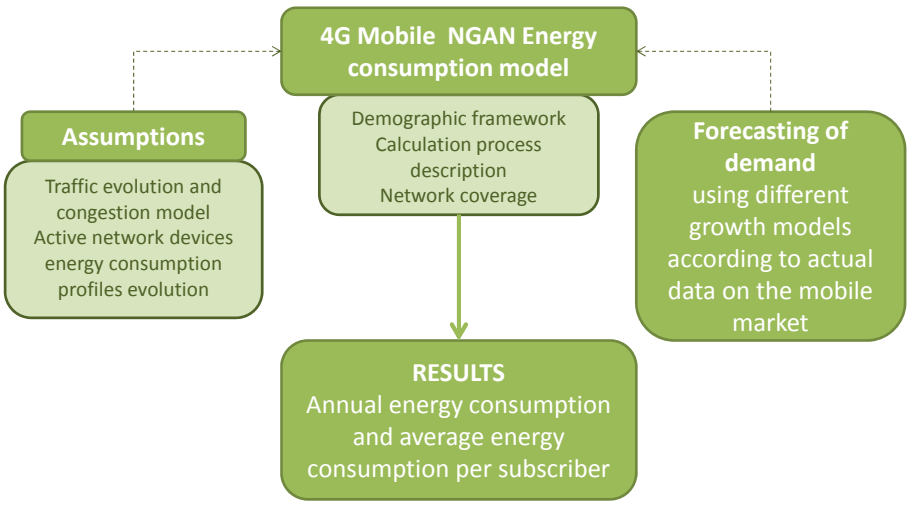
Research questions

- **What are the network related parameters that define the future scenarios in terms of energy consumption in mobile networks?**
- **How a variation on these parameters levels affects the energy consumption estimations?**

Motivation

- 4G Networks → Alternative to fixed networks
- Energy model. A thorough analysis in terms of identifying and defining clearly the future scenario of diverse network related parameters:
  - ***Demand***
  - ***Traffic***
  - ***Usage during the day***
  - ***Device energy consumption***
  - *Energy price*
  - *Demographic changes*
- The complexity lies on the proper **combination of those parameters** and their introduction in the model proposed.
- The analysis of the results would help us determine the **relative importance** of each factor and the need of improving the accuracy on the calculation of each of them.

Energy model complete framework



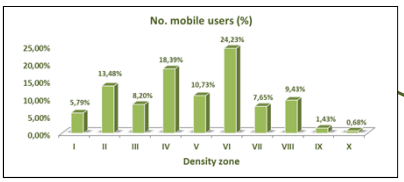
Demographic framework

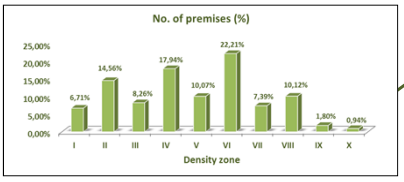
MODEL
ASSUMPTIONS
RESULTS
DEMAND FORECASTING

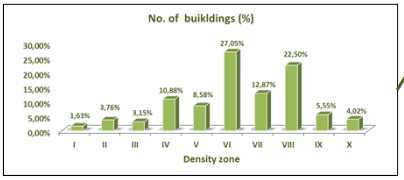
- **Spain** is used as a case study (applicable without major modifications to other countries).
- Classification in **10 geographical zones** with **population density** as the basic parameter.
- The model allows for more precise **estimations in the areas where only one broadband network operator is present**
- **To improve the lack of information on buildings clustering**, mainly for suburban and rural areas → Division of each zone in **2 different geotypes "A" & "B".**

Demographic framework in numbers

MODEL
ASSUMPTIONS
RESULTS
DEMAND FORECASTING





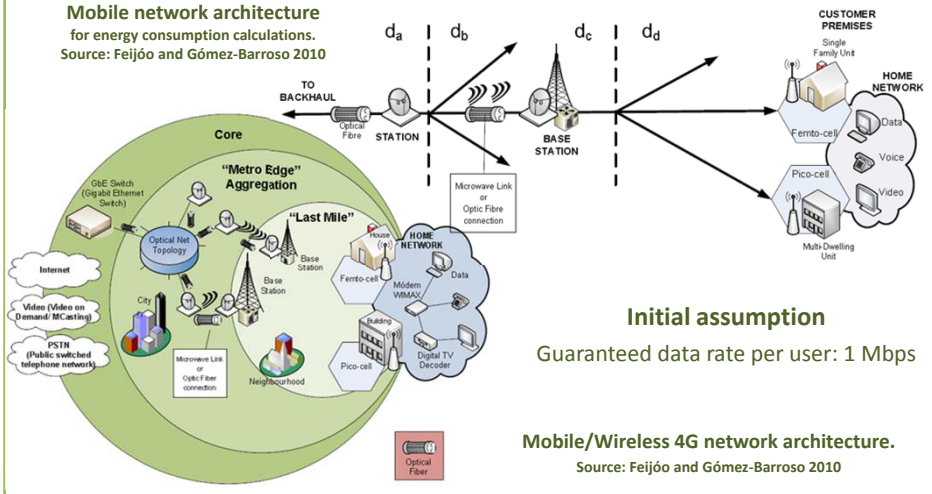


SPAIN	
Number of municipalities	8112
Total population (inhabitants)	46.745.807
Mobile penetration rate (CMT, October 2010)	121%
Total number of mobile users	56.562.426
Number of households an businesses	17.950.398
Global average mobile users per premise	3,15
Number of buildings	9.285.007
Global average mobile users per building	10,08
Average population (inhabitants per municipality)	5.763
Total surface (km2)	504.677
Average surface per municipality (km2)	62,21

4G Access network architecture

MODEL
ASSUMPTIONS
DEMAND FORECASTING
RESULTS

Mobile network architecture
for energy consumption calculations.
Source: Feijóo and Gómez-Barroso 2010



Initial assumption

Guaranteed data rate per user: 1 Mbps

Mobile/Wireless 4G network architecture.
Source: Feijóo and Gómez-Barroso 2010

4G Access network architecture

MODEL
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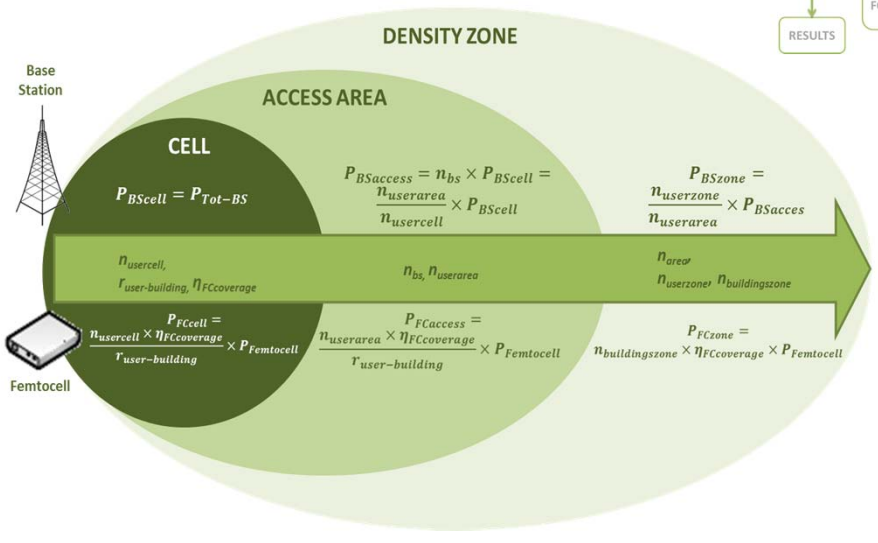
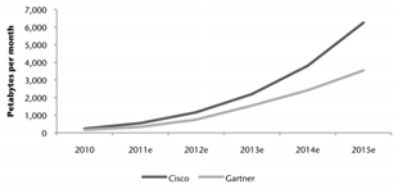


Traffic evolution

MODEL
ASSUMPTIONS
RESULTS
DEMAND FORECASTING

Average data rate
Global data traffic model
Evolution pattern
Peak data rate
Network congestion model
Quality level
Max. data rate per user
Usage features
Number of simultaneous users
Network resizing
Data intensive applications Video



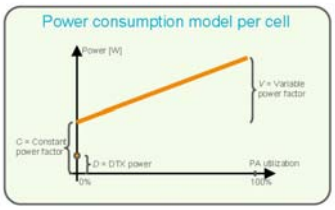
Global Mobile Data Traffic Forecasts 2011-2015.
Source: IMF (WEO database); Cisco Visual Networking Index, June 2011; Gartner Forecast Mobile Data Traffic and Revenue, worldwide 2010-2015; Jefferies & Co.

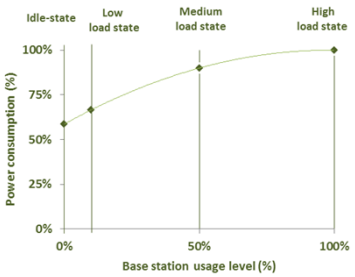
Active device energy profiles

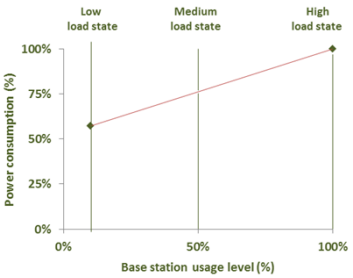
MODEL
ASSUMPTIONS
RESULTS
DEMAND FORECASTING

Reference idea

Source:
Frenger, P., Moberg, P., Malmodin, J., et al. (2011). "Reducing Energy Consumption in LTE with Cell DTX".





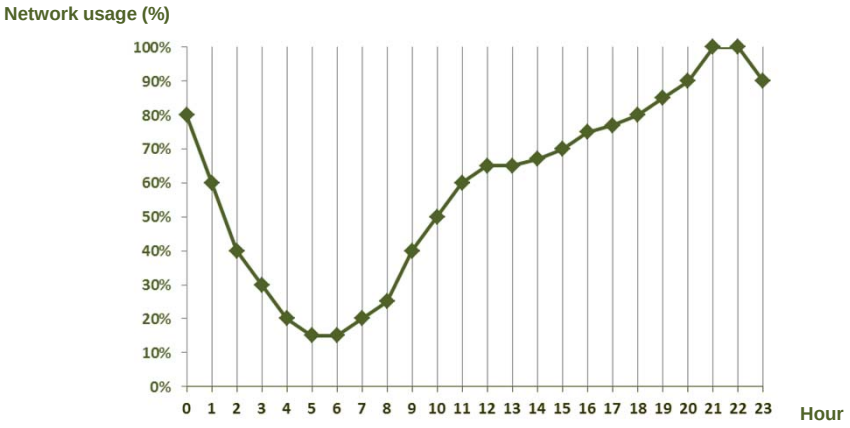


Base Stations energy consumption model

Femtocell energy consumption model

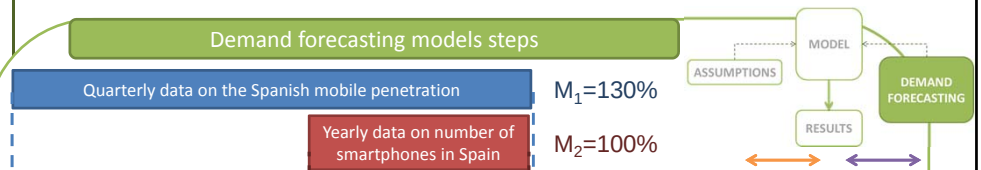
Network daily usage

- Instead of assuming a 100% work cycle at all times for the devices an average daily profile of network usage is used



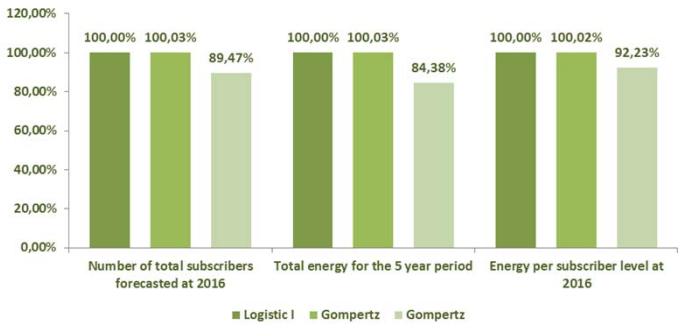
Data traffic variation during a day
Source: Project EARTH

Demand forecasting models steps



Main results
Demand forecasting results

MODEL
ASSUMPTIONS
DEMAND FORECASTING
RESULTS



Calculations % taking the Logistic I model as a reference

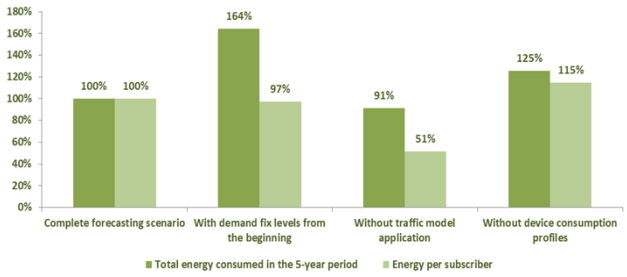
	Logistic I	Logistic II	Gompertz
Mobile penetration saturation level reduction of 5%	-6,9%	-6,9%	-6,0%
Smartphone market saturation level reduction of 10%	-9,2%	-9,3%	-5,6%

Effect of market saturation variation in the different stages of demand forecasting on the total energy consumption along the 6-year period

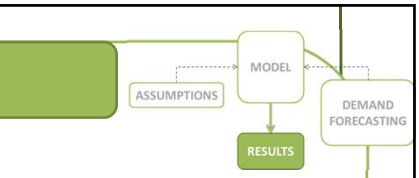
Main results
Sensitivity analysis

MODEL
ASSUMPTIONS
DEMAND FORECASTING
RESULTS

- ***Comparisons with the complete forecasting scenario.***
- ***Main variations:***
  - ***No demand variation:*** Complete coverage of the demographic scenario according to penetration levels assumed for the entire 6-year period
  - ***No traffic model:*** No variations on the mobile data traffic along the years
  - ***No device consumption variation and 24/7 network usage at 100% level along the entire year***



Main results
Sensitivity analysis



Changes in demand

- Fixed demand along the 6-year scenario
- Saturation levels in forecasting processes variation
- Subscriber allocation strategy changes from high density to low density
  56% increase

Traffic variations

- Congestion model
- Fixed guaranteed data rate for all years
  - 1 Mbps
    26% reduction,
    but QoS levels cannot be met through 2014-2016
  - 5 Mbps
    23% reduction

Device improvement

- No workload daily profile
  13% increase
- Energy consumption profiles
  12% increase
- Lack of device's energy features improvement
  - Femtocells
    10% increase
  - Base stations
    2% increase

Conclusions (I)

- This study considers three main effects in the energy consumption of a 4G NGAN, each of them impacts significantly in the energy consumption of the access network.
  1. The **adoption** of the network (evolution of take-up as the network is deployed)
  2. Yearly **traffic** evolution (scaling up of data traffic per user, both average and peak due to new applications and new users), quality of service and network congestion
  3. The **daily traffic pattern** and energy **consumption profiles** of network devices
- The variation on the different models used for demand forecasting influences the final results. Variations on the approach using the same model do not have significant effect.
- The model is highly dependent on the market saturation levels estimated for each forecasting stage.
- **The demand is a significant factor that requires and accurate calculation.**

Conclusions (I)

- Subscriber distribution on the deployed network is also a factor of high importance and should be carefully estimated.
- Traffic congestion model usage translates into and increase of 9% in energy consumption. This assuming some changes along the years in data rate per user to accommodate to traffic variations.
- Data rate per user estimation is a critical factor.
- The improvement of energy consumption profiles of the active network equipment will derive in significant energy consumption reductions.

What's next in the roadmap?

- Forecasting process: statistical measures and diffusion models improvement,…
- Application of the model to fixed NGANs to allow comparisons among the different technologies.
- Energy prices evolution
  - This further step would allow for comparisons among energy consumption costs and deployment related expenditures
- Demographic evolution forecasting
  - As a continuous varying scenario, the demographic changes should be taking into account as well.

Questions and suggestions

Contact details

Rafael Coomonte

rcoomonte@cedint.upm.es

Sergio Ramos

sramos@cedint.upm.es

CeDInt UPM, Madrid (Spain)

http://www.cedint.upm.es

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Thank you for your attention!!